WADC TECHNICAL REPORT 54-39

AN EMPIRICAL REPORT ON THE EFFECT OF POLYVINYL BUTYRAL ON CARGO-PARACHUTE SHROUD LINES

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WRIGHT AIR DEVELOPMENT CENTER

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Carpenter Litho & Prtg. Co., Springfield, O.
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FOREWORD

This report was prepared by Thomas Taylor & Sons, under USAF Contract No. AF 33(600)-23556. The contract was initiated under Research and Development Order No. 612-12(A-I), "Textiles for High Speed Parachutes", and was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Miss Joyce McGrath acting as project engineer.

ABSTRACT

Each of the shroud lines enumerated in the Military Specification MIL-C-7515 (USAF) was treated with polyvinyl butyral at varying percent concentrations, and then tested for breaking strength, abrasion resistance, and weathering resistance.

On correlation of the resulting data, it was found that variation of the polyvinyl butyral content did not effect appreciably either the original breaking strength, or the breaking strength after weathering of the Types I through V. High contents adversely effected the shear resistance with respect to the larger shroud lines. The abrasion resistance was continuously improved in most instances with increasing resin content with no evidence of an asymptote being approached except in the case of Type V.

The 5% tentatively set as limit of variation in resin content is insufficient for practical purposes. It is recommended that final specification be so written as to permit a 25% tolerance in resin content.

For this project, by careful control, we maintain resin content within the 5% limit in most items.

Elongation of untreated and treated braids was recorded on Types I through IV, which provides data for comparison of treated and untreated braid. Elongation on Type V through X could not be taken because of danger to operators.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. R. WHITMORE
Technical Director
Materials Laboratory
Directorate of Research

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I. INTRODUCTION

A. Objective

The object of this research was to provide data on the physical characteristics of cargo parachute shroud lines when these lines have been treated with a water emulsion of polyvinyl butyral. The intent was to ascertain the resin content that would contribute most to the functional characteristics of the shroud lines.

The ten types of shroud lines described in Military Specification MIL-C-7515 (USAF) were manufactured in sufficient quantities for this purpose under more rigid control conditions than could be expected on a production basis. Each of the ten types was divided into four groups. One group was retained as a control; the remaining groups were treated with the resin so that the percent content, on a dry basis, was 2, 3 and 4% respectively.

B. Testing

After conditioning at standard conditions, each of the four groups was tested for:

a. Original breaking strength
b. Breaking strength after abrasion
c. Breaking strength after accelerated weathering

The resulting data was then tabulated and graphed.

II. PROCEDURE

A. General Information

The tests described below were conducted on forty samples of each type. These forty samples were divided into groups of ten, each group representative of a given percent of resin content, ie: 0, 2, 3 and 4%. One exception was made to the above. The larger braids that had been treated at approximately 4% resin content could not be tested without obtaining a jaw break, so that in some instances, the number of tests reported is five.

B. Uniformity of Production

As can be seen in Table II, the picks per a five inch length was determined at periodic intervals throughout the entire yardage produced for Types I through VIII. A ten inch gage length was used for Types IX and X. Such gage lengths were used in order to provide a sufficient number of picks to assure accuracy. The picks were measured while the braid was relaxed.

C. Linear Weight

The linear weight was determined by measuring a two yard length while under a load of ten pounds. The two yard length was then cut at the gage marks and weighed.

D. Breaking Strength

The yarn employed in manufacturing the braid was tested on a model IP-4 and found to be extremely consistent.

The model Q produced by Scott Testers Inc. was employed for the braids breaking below 1,500 pounds. The Universal Tester produced by Dillon & Company Inc. was used on all types breaking above 1,500 pounds. A 5,000 pound capacity dynameter was used, whenever possible and a 10,000 pound capacity dynameter used in those instances, where the breaking strength was greater than 5,000 pounds. The Universal is rated as having an accuracy within 2% of full capacity. The accuracy of the model Q is much greater than that of the Universal. Split barrel clamps were used on both machines.

E. Abrasion Resistance

The abrasion resistance was measured on a machine manufactured by this firm in compliance with the requirements set forth in Specification MIL-W-4088. The machine was calibrated by running a series of twenty-five tests per Types II, V and VIII. Each test consisted of 5,000 strokes over a hexagonal bar as supplied by Wright Air Development Center. From the results of the calibration runs the bar was considered to be in a conditioned state between tests five and twenty-five. See Table V for calibration data. The influence of the weight attached to the braid as it was being test-

ed was also investigated by a series of five tests, using a two pound weight in the first group and a 5.2 pound weight in the second group. There was no detectable difference in the resulting breaking strength. However, Types I through IV were run with the two pound weight and the remainder run with the 5.2 pound weight.

All abrasion tests were run on conditioned hexagonal bars for 5,000 strokes and then tested for breaking strength after conditioning for 24 hours at 70 degrees Fahrenheit and 65% RH.

F. Weathering Resistance

Samples of each type were exposed in a Weatherometer for a period of 100 hours with the spray heads shut off during the entire exposure period. The air temperature was held at 135 degrees Fahrenheit plus or minus 10 degrees Fahrenheit. The samples were conditioned after exposure and then tested for breaking strength.

G. Analysis of Resin Content

Approximately five gram samples were dried to a constant weight in an oven at 110 degrees C. The samples were then weighed in a weighing bottle. The samples were then shredded and extracted with methyl ethyl ketone for a period of six hours in a soxhlet apparatus. The extracted samples were then dried and weighed as before.

Five blank extractions were made on untreated braid on Types I, II, III, V, VII, IX and X. The figures for those braids constructed with 210/3 Nylon were averaged and the average taken as the substract in calculating the resin content in all treated braids. The same procedure was followed for those braids constructed of 210/4 Nylon.

See Table VII for blank extraction data.

$$\text{Percent Resin} = \frac{\text{loss in weight on extraction - blank average}}{\text{original dry weight}} \times 100$$

III DISCUSSION OF RESULTS

A. General

Although evaluation of the data presented in this report is the function of the project engineer and not that of the writer, the conclusions drawn by the writer, which had an effect on the method of presenting the data are given below.

Table XIII presents the average of all the pertinent data acquired. The accompanying graphs, Figures 1 and 2, were produced from Table XIII. The breaking strength after abrasion was the only characteristic plotted, since neither original breaking strength nor breaking strength after weathering varied more than the inherent accuracy of the testing methods; consequently, the significance of the data for both characteristics can be appreciated readily by examination of the Tables.

B. Breaking Strength

From examination of Table XIII, it could be concluded that the amount of polyvinyl butyral present in the braid has no appreciable effect upon the breaking strength of Types I through V. The data for Types VI through X show a decided drop in breaking strength at the higher resin contents. If the reader will now turn to Table X of the data section, he will note that the average (which is the figure reported in Table XIII) is obtained by including tests that resulted in jaw breaks and, therefore, does not represent the true breaking strength of the braid. Although ordinarily unorthodox, these data were included, because the consistent occurrence and type of jaw break was considered significant. These breaks occurred on the heavier braids at the higher resin contents and never appeared elsewhere. Each sample was found to have been severed at the point, where the edges of the split barrel contacted the surface of the braid. The action was much like that of a pair of dull scissors. The conclusion was that this effect was a function of both the resin content and the material bulk of the braid. Both factors influence flexibility, as both increase, the ability of the individual filament to reorient diminishes. The incident of jaw breaks, consequently, is considered reportable data, and a qualitative approach to shearing resistance.

After examination of Table X, the inclusion of Type V with Types VI through X appears proper due to the appearance of jaw breaks even though the resulting average does not reflect any loss in breaking strength. In summation, it appears that the practical limit of resin content, when considering its effect on breaking strength, is reached below four percent for Types V through X and is reached at some figure above four percent for Types I through IV.

III. DISCUSSION OF RESULTS (continued)

C. Abrasion Resistance

Only Type V, of the ten types of shroud lines, exhibits a tendency to approach an asymptote. Type I exhibits no improvement in abrasion resistance over the range of resin contents studied. The remaining types all improve in varying degrees with increasing resin content. Evidently, higher resin contents would have to be investigated to determine where a plateau would be obtained. There are two noteworthy characteristics to be observed from Table XIII and the abrasion graphs, figures 1 and 2. First, the larger the braid, the greater the percent loss in breaking strength after abrasion.

(i.e: $\frac{\text{Breaking Strength, Original - Breaking Strength after Weathering}}{\text{Breaking Strength, Original}} \times 100$

Second, the greater the loss at 0% resin content, the greater the improvement in abrasion resistance with increasing resin content.

Although not within the scope of this report, an evaluation of the phenomena of increased loss, percentage wise, in abrasion resistance as the weight and size of the braid increases from that of Type I through that of Type X might be of interest in clarifying the influence of braid structure upon abrasion resistance. In view of the fact that the resin influences the weight of the braid, the observed weight would not be the proper variable to correlate with percent abrasion resistance. Accordingly, the linear filament density

$$\frac{\text{Picks}}{\text{Inch}} \times \frac{\text{Ends}}{\text{Carrier}} \times \frac{\text{Denier}}{\text{End}}$$

was used instead. The figures obtained are reported in Table XIV This factor is useful in evaluating structual influence upon breaking strength, but, unfortunately did not provide a continuous curve, when plotted against percent abrasion resistance. However, such a plot suffers from the assumptions that the surface area of the braid is proportional to the number of carriers used and the ratio of a braided surface area to total surface area does not vary from one braid to another. The first assumption is reasonably valid, but the second needs investigation. In plotting picks per inch against percent abrasion resistance, a trend is obtained of lower resistance with less picks, a result that is almost too obvious. However, it can be concluded that the larger braids might prove more efficient, if manufactured on a braiding machine with more carriers, thus providing an opportunity to produce a braid of the same breaking strength with more picks per inch.

Since the graphs of the above do not produce a precise curve, and, since this investigation is not within the sphere of this report, any more formal analysis is left to the discretion of the reader. Table XIV presents the data used as basis for the above statements.

D. Weathering Resistance

The resin content is not a function of the degree of weathering resistance. When viewing the percent loss in breaking strength

(i.e: $\frac{\text{Breaking Strength, Original - Breaking Strength after Weathering}}{\text{Breaking Strength, Original}} \times 100$

a rather large range is seen, from negligible for Type I at 0% to 13.6% for Type III at 2% resin content. The average loss is 7 to 8%, however, regardless of the resin content.

The larger types, once again, produce a preponderance of jaw breaks. Since the braid in contact with the clamps was not exposed in the weatherometer (only the section between the clamps being so exposed) jaw breaks can be expected for the same reason as for those obtained for the breaking strength of the unexposed braid.

TABLE I

PHYSICAL PROPERTIES OF BRAID, SPECIFICATION MIL-C-7515(USAF)

Type	No. of Carriers	Picks per Inch	Ends per Carrier	Total Ends	Weight, Yards per Pound Minimum	Breaking Strength Pounds Minimum	Elongation percent Minimum	Yarn Ply
I	16	11.5-13.0	3	48	110	400	20	3
II	16	10-11.5	3	48	85	550	20	4
III	16	8.5-10	6	96	50	750	20	3
IV	16	7-8.5	6	96	40	1,000	20	4
V	16	6.5-8	9	144	25	1,500	20	4
VI	16	4.5-6	12	192	20	2,000	--	4
VII	16	4.5-6	14	224	15	2,400	--	4
VIII	24	5.5-7	12	288	12	3,000	--	4
IX	32	5.5-7	12	384	9	4,000	--	4
X	32	4.5-6	16	512	7.5	5,000	--	4

TABLE II

DATA FROM INVESTIGATION

OF UNIFORMITY OF CONSTRUCTION

YARDS	I	II	YARDS	III	IV	V
	Picks			Picks		
50	64.0	53.7	25	46.6	37.3	36.0
100	63.3	53.5	50	46.8	37.3	35.8
150	62.5	52.8	75	47.0	36.8	35.6
200	61.5	52.8	100	46.5	37.0	36.5
250	61.7	52.5	125	47.0	37.7	36.6
300	62.5	52.8	150	46.5	36.8	36.8
350	62.7		175	46.7	36.6	36.6
400	62.0		200	47.2	38.0	36.0
450	62.7		225	47.5	37.8	
500	61.5		250	47.0	37.7	
550	62.5		275	46.5	36.8	
600	62.0		300	47.5	37.0	

YARDS	VI	VII	YARDS	VIII	YARDS	VIII
	Picks			Picks		Picks
25	26.0	26.7	15	30.6	240	29.8
50	26.5	26.5	30	31.0	255	29.8
75	25.9	27.9	45	30.3	270	29.8
100	26.5	26.3	60	30.6	285	30.0
125	26.5	26.3	75	29.5	300	30.5
150	25.5	26.8	90	30.3	315	30.6
175		26.3	105	30.5	330	29.7
200		27.4	120	30.0	345	30.0
225		26.8	135	30.3	400	30.3
250		26.0	150	30.5		
275		26.0	165	29.8		
300		26.4	180	30.5		
325		26.3	195	30.7		
350		26.4	210	30.5		
380		26.5	225	30.3		

NOTE: Picks as given here are the number in a five inch length.

TABLE II

DATA FROM INVESTIGATION

OF UNIFORMITY OF CONSTRUCTION

(continued)

YARDS	TYPE IX	TYPE X
	Picks	Picks
10	62.3	51.5
20	64.0	51.0
30	62.8	51.4
40	63.5	51.5
50	62.3	49.8
60	62.7	50.4
70	61.8	50.7
80	62.9	52.0
90	63.0	49.5
100	62.4	50.8
110	62.3	51.0
120	61.8	51.3
130	62.7	50.5
140	63.0	49.8
150	62.3	50.3
160	61.0	50.5
170	62.5	51.5
180	62.6	
190	61.8	
200	61.6	
210	62.3	
220	62.0	
230	61.0	
240	61.7	

NOTE: Picks as given here are the number in a ten inch length.

TABLE III

CONDITIONED WEIGHTS OF

UNTREATED BRAID

TYPE	Yards/Pounds	TYPE	Yards/Pounds
I	122	VI	23.2
II	91.5	VII	19.0
III	59.7	VIII	14.6
IV	45.3	IX	10.7
V	22.9	X	8.1

NOTE: The above data are the resulting average of ten determinations per type. None of the original values varied by more than one-half of one percent from the average.

TABLE IV

BREAKING STRENGTH OF YARN AS

RECEIVED FROM SUPPLIER

210/3	KILOGRAMS	210/4
4.98		6.72
5.01		6.72
5.04		6.68
5.10		6.72
4.98		6.72
5.01		6.72
5.06		6.65
4.83		6.66
4.89		6.70
4.98		6.72
4.98		6.80
5.01		6.68
5.04		6.68
5.04		6.76
5.07		6.25

TABLE V

CORRELATION DATA - EXTENT OF ABRASION

VS.

NUMBER OF PRIOR TESTS CONDUCTED ON HEXAGONAL ROD

BREAKING STRENGTH OF ABRADED UNTREATED BRAID (Pounds)				PICKS - 5" Lengths (Before Abrasion)			
	TYPE				TYPE		
Test No.	II	V	VIII	Group	II	V	VIII
1	342	892	1,550	5	51.5	35.7	29.5
2	332	956	1,500	6	52.5	36.0	30.4
3	362	938	1,475	7	52.5	36.5	31.0
4	308	940	1,600	8	51.5	36.0	30.3
5	382	924	1,450	9	51.0	36.2	31.0
6	338	942	1,575	11	51.8	36.0	29.4
7	370	984	1,575	12	52.5	35.7	30.3
8	338	950	1,475	13	51.3	36.0	29.7
9	338	948	1,475	14	52.0	36.3	30.4
10	336	918	1,500	15	52.4	36.4	30.0
11	340	978	1,675	16	52.3	36.8	30.6
12	346	962	1,500	17	52.0	35.9	30.0
13	346	930	1,575	18	51.5	36.7	30.5
14	362	954	1,700	19	52.4	36.3	30.8
15	356	926	1,550				
16	368	930	1,450				
17	362	942	1,525				
18	344	948	1,675				
19	338	950	1,575				
20	334	960	1,525				
21	332	930	1,600				
22	348	946	1,475				
23	356	928	1,600				
24	366	958	1,525				
25	366	906	1,550				

TABLE VI

NOMINAL CONCENTRATIONS vs. ACTUAL CONCENTRATIONS

OF POLYVINYL BUTYRAL (%)

NOMINAL:	2	3	4
TYPE	ACTUAL CONCENTRATIONS		
I	1.84	3.16	3.92
II	2.10	3.03	4.19
III	2.21	3.22	3.84
IV	1.78	2.81	4.04
V	2.25	3.06	4.25
VI	2.19	3.18	4.40
VII	2.06	3.22	3.82
VIII	2.27	2.94	3.98
IX	1.84	2.78	3.96
X	2.10	3.47	4.45

TABLE VII

RESULTS OF EXTRACTIONS PERFORMED

ON UNTREATED BRAIDS

TYPE	% Solids Extracted					YARN COUNT
SAMPLE	1	2	3	4	5	
I	0.77	0.76	0.80	0.80	0.77	210/3
II	0.54	0.55	0.56	0.55	0.56	210/4
III	0.74	0.81	0.79	0.80	0.78	210/3
V	0.58	0.54	0.52	0.55	0.53	210/4
VII	0.51	0.54	0.53	0.54	0.56	210/4
IX	0.54	0.52	0.50	0.53	0.53	210/4
X	0.56	0.55	0.58	0.58	0.59	210/4

AVERAGE:

210/3: 0.78

210/4: 0.55

TABLE VII I

ANALYSIS OF RESIN TREATED

EXPERIMENTAL BRAID

MATERIAL Type	RESIN Nominal	SAMPLE	% SOLIDS	BLANK Average	% RESIN Average
I	2%	A	2.67	0.78	
		B	2.50		
		C	2.74		
					1.86
	3	A	4.25	0.78	
		B	3.80		
		C	3.77		
					3.16
	4	A	4.74	0.78	
		B	4.56		
		C	4.78		
					3.92
II	2	A	2.85	0.55	
		B	2.43		
		C	2.67		
					2.10
	3	A	3.83	0.55	
		B	3.67		
		C	3.24		
					3.03
	4	A	4.61	0.55	
		B	4.78		
		C	4.83		
					4.19
III	2	A	3.04	0.78	
		B	2.79		
		C	3.14		
					2.21
	3	A	3.87	0.78	
		B	4.33		
		C	3.80		
					3.22
	4	A	4.87	0.78	
		B	4.36		
		C	4.63		
					3.84
IV	2	A	2.53	0.55	
		B	2.10		
		C	2.36		
					1.78
	3	A	3.63	0.55	
		B	3.10		
		C	3.35		
					2.81

TABLE VIII

ANALYSIS OF RESIN TREATED

EXPERIMENTAL BRAID
(continued)

MATERIAL	RESIN	SAMPLE	% SOLIDS	BLANK	%RESIN
Type	Nominal			Average	Average
IV	4%	A	4.53	0.55	
		B	4.35		
		C	4.88		
					4.04
V	2	A	2.60	0.55	
		B	2.76		
		C	3.04		
					2.25
	3	A	3.65	0.55	
		B	3.38		
		C	3.80		
					3.06
	4	A	5.12	0.55	
		B	4.95		
		C	5.34		
					4.25
VI	2	A	2.81	0.55	
		B	2.83		
		C	2.58		
					2.19
	3	A	3.74	0.55	
		B	3.56		
		C	3.88		
					3.18
	4	A	4.98	0.55	
		B	4.81		
		C	5.06		
					4.40
VII	2	A	2.54	0.55	
		B	2.75		
		C	2.53		
					2.06
	3	A	3.68	0.55	
		B	3.75		
		C	3.88		
					3.22
	4	A	4.14	0.55	
		B	4.26		
		C	4.61		
					3.82
VIII	2	A	2.51	0.55	
		B	2.94		
		C	3.02		
					2.27
	3	A	3.44	0.55	
		B	3.38		
		C	3.64		
					2.94

TABLE VII I

ANALYSIS OF RESIN TREATED

EXPERIMENTAL BRAID
(continued)

MATERIAL	RESIN	SAMPLE	% SOLIDS	BLANK	% RESIN
Type	Nominal			Average	Average
VIII	4%	A	4.73	0.55	
		B	4.50		
		C	4.37		
					3.98
IX	2	A	2.34	0.55	
		B	2.25		
		C	2.48		
					1.84
	3	A	3.29	0.55	
		B	3.22		
		C	3.48		
					2.78
	4	A	4.68	0.55	
		B	4.40		
		C	4.45		
					3.96
X	2	A	2.87	0.55	
		B	2.46		
		C	2.62		
					2.10
	3	A	4.16	0.55	
		B	4.16		
		C	3.74		
					3.47
	4	A	5.03	0.55	
		B	5.24		
		C	4.75		
					4.45

TABLE IX

BREAKING STRENGTH AND ELONGATION OF UNTREATED BRAID (0% POLYVINYL BUTYRAL OR RESIN)

TYPES I THROUGH IV

Type I Breaking Strength: (Pounds)	Elongation(%)	Type II Breaking Strength: (Pounds)	Elongation(%)
402	48	580	50
408	52	576	46
408	48	568	44
402	48	562	48
402	52	586	44
412	48	578	46
406	50	582	52
400	50	580	50
410	50	572	48
408	50	578	42
		Average	
406	50	576	47

Type III Breaking Strength: (Pounds)	Elongation(%)	Type IV Breaking Strength: (Pounds)	Elongation(%)
862	46	1,142	42
872	54	1,170	40
864	52	1,170	46
866	50	1,164	44
878	52	1,160	38
868	48	1,164	40
870	50	1,170	40
870	52	1,142	40
868	52	1,164	50
862	50	1,166	40
		Average	
868	51	1,160	42

TABLE IX

BREAKING STRENGTH AND ELONGATION

OF UNTREATED BRAID

(0% POLYVINYL BUTYRAL OR RESIN)
(continued)

TYPES V THROUGH X

Breaking Strength: (Pounds) V	VI	VII	VIII	IX	X
1,650	2,275	2,875	3,825	4,650	6,300
1,725	2,325	2,850	3,600	4,800	6,600
1,675	2,350	2,625	3,600	4,500	6,400
1,675	2,450	2,550	3,450	4,900	6,400
1,625	2,475	2,725	3,675	4,600	6,200
1,700	2,550	2,825	3,550	4,700	6,450
1,650	2,375	2,875	3,600	4,600	6,250
1,750	2,700	2,800	3,450	4,500	6,150
1,700	2,650	2,475	3,625	4,800	6,250
1,700	2,225	2,850	3,425	5,000	
			Average		
1,685	2,438	2,745	3,580	4,700	6,300

TABLE X

PHYSICAL CHARACTERISTICS

OF RESIN TREATED BRAID

TYPE I	2%		TYPE II	2%	
Picks/5"	Breaking Strength: (Pounds)	Elongation (%)	Picks/5"	Breaking Strength: (Pounds)	Elongation (%)
59	422	42%	49	590	40%
59	422	40	48.5	580	38
59	420	40	48.5	580	40
59	420	42	48.5	582	38
59	422	40	48.5	584	38
59	422	42	49	584	42
59	426	36	48.5	582	38
59	422	40	48.5	590	42
59	420	42	49	584	40
59	430	44	48.5	584	44
Average:	423	41		584	40
	3%			3%	
58 5	424	42%	48.5	584	42%
58.5	420	42	49	580	40
58.5	420	44	49	586	40
58.5	420	42	49	578	42
58.5	424	42	49	586	44
58.5	416	40	49	590	42
58	422	40	48.5	584	40
58	430	42	48.5	588	40
59	424	42	48.5	588	42
58.5	422	40	49	586	40
Average:	422	42		585	41
	4%			4%	
57.5	426	36%	48	584	38%
57.5	422	36	48.5	590	40
57.5	418	36	49	584	40
58	426	36	48.5	586	42
57.5	426	38	48.5	524	38
57.5	426	34	48.5	592	38
58	426	38	48	586	38
58	424	36	48	588	38
58	422	38	48.5	580	38
58	426	36	48.5	590	38
Average:	424	36		580	39

TABLE X

PHYSICAL CHARACTERISTICS

OF RESIN TREATED BRAID
(continued)

TYPE III	2%		TYPE IV	2%	
Picks/5"	Breaking Strength: (Pounds)	Elongation (%)	Picks/5"	Breaking Strength: (Pounds)	Elongation (%)
43.5	842	38%	34.5	1,176	44%
43.5	818	38	33.5	1,160	42
43.5	824	37	34	1,172	45
44	818	38	34.5	1,166	40
44	820	38	34.5	1,152	42
43.5	828	38			
44	830	38			
43.5	800	35			
43.5	842	36			
Average:	824	38		1,165	43
	3%			3%	
43.5	880	45%	34.	1,176	42%
43	874	35	34	1,180	44
43.5	870	42	34	1,180	41
43.5	874	48	34	1,180	40
44.5	880	41	33.5	1,166	41
Average:	875	42		1,176	42
	4%			4%	
43.5	870	42%	34	1,176	39%
44	856	43	34	1,166	38
43.5	872	43	34	1,178	38
44	872	46	33.5	1,172	39
44	870	45	34	1,172	40
Average:	868	42		1,173	39

TABLE X

PHYSICAL CHARACTERISTICS

OF RESIN TREATED BRAID
(continued)

TYPE V	2%	TYPE VI	2%
Picks/5"	Breaking Strength: (Pounds)	Picks/5"	Breaking Strength: (Pounds)
33	1,725	24	2,550
33.5	1,650	24	2,425
33.5	1,675	24	2,400
34.5	1,850	24	2,175 JB
33.5	1,650	24	2,425
Average:	1,711		2,395
	3%		3%
34	1,750	24	2,375
34	1,750	24	2,325
33.5	1,700	24	2,350
33	1,650 JB	24	2,325
33	1,875 JB	24	2,325
Average:	1,745		2,340
	4%		4%
33.5	1,725	24	2,200 JB
34.5	1,800 JB	23.5	2,050 JB
34	1,550 JB	24	2,025 JB
33.5	1,700	24.5	2,125 JB
34	1,600 JB	24	1,950 JB
Average:	1,675		2,070

NOTE: JB - Jaw Break

TABLE X

PHYSICAL CHARACTERISTICS

OF RESIN TREATED BRAID
(continued)

TYPE VII Picks/5"	2% Breaking Strength: (Pounds)	TYPE VIII Pick/5"	2% Breaking Strength: (Pounds)
24	2,475 JB	28	3,200 JB
24	2,725	28	3,350 JB
24.5	2,675	28.5	4,000
24.5	2,850	28.5	3,550 JB
24.5	2,725	28.5	3,450
Average:	2,690		3,510
	3%		3%
24.5	2,600	27.5	3,750
24	2,775	27.5	3,150
24	2,875	27.5	3,500 JB
24.5	2,825	27.5	3,000 JB
24.5	2,700	27.5	3,100 JB
Average:	2,755		3,300
	4%		4%
24.5	2,600	27.5	2,800 JB
24.5	2,325 JB	27.5	3,750
24.5	2,375 JB	27.5	3,100 JB
24.5	2,350 JB	27.5	3,025 JB
24.5	2,475 JB	27.5	2,975 JB
Average:	2,425		3,130

NOTE: JB - Jaw Break

TABLE X

PHYSICAL CHARACTERISTICS

OF RESIN TREATED BRAID
(continued)

TYPE IX	2%	TYPE X	2%
Picks/5"	Breaking Strength: (Pounds)	Picks/5"	Breaking Strength: (Pounds)
29	5,125	24	6,600
29.5	4,125 JB	24	6,650
29.5	4,100 JB	24	6,500
29	4,950	24	6,725
29	4,950	24	5,425 JB
Average:	4,650		6,380
	3%		3%
29.5	4,625 JB	23.5	6,700
29.5	4,325	23.5	5,500 JB
29.5	5,000	23.5	6,450
30	4,850	23.5	5,050 JB
29.5	3,850 JB	23.5	5,100 JB
Average:	4,530		5,760
	4%		4%
29	4,375 JB	24	6,750
29	5,050	23.5	5,400 JB
29	4,675 JB	23.5	4,750 JB
29.5	4,100 JB	23.5	5,050 JB
29	4,125 JB	23.5	4,225 JB
Average:	4,465		5,235

NOTE: JB - Jaw Break

TABLE XI

BREAKING STRENGTHS OF ABRADED BRAIDS (POUNDS)

TYPE I				RESIN CONTENT				TYPE II
0%	2%	3%	4%	0%	2%	3%	4%	
302	336	314	338	366	376	422	452	
300	310	304	300	380	352	394	460	
300	294	328	320	380	376	432	446	
290	314	306	316	364	408	430	446	
252	310	330	336	368	370	418	450	
310	314	276	346	304	406	400	450	
290	292	320	322	390	372	384	442	
292	274	328	336	378	370	420	452	
310	304		350	374	384	420	490	
298	312		316	360	400	386	464	
Average:				Average:				
314	306	314	328	366	381	411	455	

TYPE III								TYPE IV
0%	2%	3%	4%	0%	2%	3%	4%	
546	570	688	672	636	614	690	682	
544	548	670	706	688	700	700	754	
576	578	584	700	652	648	744	682	
556	562	680	674	712	630	710	700	
584	608	642	682	596	696	704	690	
538	618	686	670	692	680	770	720	
520	586	670	712	686	654	756	778	
556	576	660	676	660	646	674	670	
496	574	640	698	648	684	746	728	
548	550	620	644	680	700	686	704	
Average:				Average:				
546	577	654	683	665	665	718	711	

TABLE XI

BREAKING STRENGTHS OF ABRADED BRAIDS (POUNDS) (continued)

TYPE V				RESIN CONTENT			TYPE VI
0%	2%	3%	4%	0%	2%	3%	4%
850	964	1,125	1,224	1,125	1,200	1,194	1,500
850	1,036	1,175	1,132	1,150	1,264	1,340	1,375
900	1,016	1,200	1,180	1,100	1,068	1,280	1,400
875	946	1,100	1,090	1,075	1,160	1,176	1,350
850	1,060	1,200	1,244	1,100	1,200	1,240	1,350
875	938	1,225	1,168	1,200	1,234	1,226	1,350
900	1,030	1,150	1,356	1,050	1,230	1,220	1,425
750	970	1,225	1,224	1,175	1,216	1,262	1,425
900	990	1,225	1,190	1,075	1,230	1,218	1,425
775JB	1,068	1,000	1,148	1,050	1,250	1,148	1,400
Average:				Average:			
853	1,002	1,163	1,196	1,110	1,205	1,230	1,400

TYPE VII							TYPE VIII
0%	2%	3%	4%	0%	2%	3%	4%
1,200	1,348	1,398	1,775	1,675	1,650	1,725	1,900
1,125	1,336	1,366	1,975	1,500	1,575	1,600	2,050
1,150	1,384	1,394	2,025	1,575	1,600	1,725	2,100
1,175	1,390	1,520	1,775	1,700	1,500	1,650	2,050
1,150	1,392	1,450	1,850	1,550	1,575	1,675	1,950
1,125	1,302	1,475	1,975	1,450	1,525	1,750	1,950
1,075	1,244	1,450	1,800	1,525	1,600	1,775	1,900
1,125	1,300	1,600	1,750	1,675	1,425	1,725	1,975
1,125	1,366	1,525	1,550	1,575	1,550	1,700	2,000
1,250	1,270	1,475	1,550	1,525	1,625	1,775	1,975
Average:				Average:			
1,150	1,333	1,465	1,803	1,575	1,563	1,710	1,985

TABLE XI

BREAKING STRENGTHS OF

ABRADED BRAIDS (POUNDS)
(Continued)

TYPE IX		RESIN CONTENT		TYPE X			
0%	2%	3%	4%	0%	2%	3%	4%
1,600	2,100	2,025	2,300	2,050	2,525	3,775	3,900
1,675	1,950	1,825	2,525	2,125	2,450	3,300	4,175
1,775	1,925	1,950	2,375	2,375	2,625	3,425	3,725
1,725	1,850	2,075	2,475	1,975	2,950	3,275	3,850
1,575	1,975	2,000	2,450	2,150	2,475	2,750	3,950
1,550	2,000	2,000	2,300	2,050	2,725	3,200	4,050
1,550	1,950	1,900	2,275	2,325	2,675	3,375	4,175
1,550	1,725	2,000	2,500	2,450	2,700	3,300	4,025
1,550	1,875	2,100	2,650	2,475	2,625	3,500	4,100
1,550	2,125	1,975	2,225	2,225	2,650	3,575	3,825
Average: 1,610	1,948	1,985	2,408	Average: 2,220	2,640	3,348	3,980

TABLE XII

BREAKING STRENGTH OF BRAID AFTER ACCELERATED WEATHERING (POUNDS)

MATERIAL: TYPE I				RESIN CONTENT			TYPE II
0%	2%	3%	4%	0%	2%	3%	4%
416	398	392	394	550	564	514	538
410	392	392	404	560	540	566	550
420	402	390	402	562	540	550	524
400	400	394	404	534	542	552	570
412	392	400	400	504	536	524	560
420	408	394	388	568	542	548	550
420	408	394	410	552	518	516	544
420	400	390	394		548	540	510
416	402	394	406		530	520	542
416	400	412	400		532	510	524
Average:				Average:			
415	400	395	400	547	539	534	541

MATERIAL: TYPE III				RESIN CONTENT			TYPE IV
0%	2%	3%	4%	0%	2%	3%	4%
854	756	820	806	1,138	1,058	1,000	1,100
848	776	818	786	1,148	1,098	1,088	1,046
868	750	820	780	1,116	1,126	1,144	1,122
850	750	810	846	1,072	1,054	1,100	1,068
853	760	814	800	1,108	1,074	1,124	1,096
854	756	794	810	1,150	1,120	1,110	1,054
850	760	814	774	1,096	1,118	1,056	1,040
854	740	786	830	1,156	1,060	1,050	1,100
850	702	810	814	1,130	1,119	1,076	1,078
854	740	808	786	1,116	1,118	1,106	1,122
Average:				Average:			
854	746	809	803	1,123	1,095	1,085	1,083

TABLE XII

BREAKING STRENGTH OF BRAID AFTER ACCELERATED WEATHERING (POUNDS) (Continued)

MATERIAL: TYPE V — RESIN CONTENT — TYPE VI

0%	2%	3%	4%	0%	2%	3%	4%
1,850	1,600	1,525	1,750	2425	2,300	2,225	2,000JB
1,800	1,625	1,350JB	1,700	2400	2,050JB	2,220	1,850JB
1,725	1,600	1,475	1,475JB	2375	2,025JB	2,275	1,900JB
1,850	1,700	1,850	1,675	2450	2,350	2,500	1,900JB
1,675	1,675	1,450	1,300JB	2250JB	2,075JB	2,275	2,175
2,075	1,550	1,450	1,250JB	2475	2,000JB	2,000JB	2,000JB
1,800	1,650	1,375	1,200JB	2400	2,800	2,500	2,450
1,450	1,650	1,500	1,275JB	2425	2,000JB	2,400	1,800JB
1,700	1,700	1,450	1,500JB	2300JB	2,095JB	2,050	1,850JB
	1,450	1,475	1,250JB	2375	2,275JB	2,225	1,950JB
Average:				Average:			
1,769	1,620	1,490	1,438	2390	2,195	2,265	1,988

MATERIAL: TYPE VII — RESIN CONTENT — TYPE VIII

0%	2%	3%	4%	0%	2%	3%	4%
3,000	2,750	2,750	2,200JB	3,150	3,700	3,500	3,500
2,225JB	2,350	2,625	2,375	3,700	3,675	3,475	3,100JB
2,650	2,150JB	2,600	2,400	3,675	3,000JB	3,700	3,125
2,800	2,400	2,250JB	2,225JB	3,700	3,100JB	3,500	3,700
2,600	2,975	2,800	2,100JB	3,800	3,150JB	3,475	3,275
2,800	2,800	2,750JB	2,100JB	3,850	3,850	3,575	3,100
2,675	2,900	2,550	2,275	3,500	2,950JB	3,400	3,625
2,825	2,975	2,700	2,450	3,750	3,750	3,550	3,200
2,275	2,875	2,650	2,525	3,850	3,200JB	3,775	3,750
2,350	2,900	2,850	2,500		3,050JB		3,500
Average:				Average:			
2,620	2,708	2,653	2,315	3,673	3,343	3,550	3,388

TABLE XII

BREAKING STRENGTH OF BRAID AFTER ACCELERATED WEATHERING (POUNDS) (Continued)

MATERIAL: TYPE IX				TYPE X			
		RESIN CONTENT					
0%	2%	3%	4%	0%	2%	3%	4%
4,850	4,600	4,800	4,475	6350	5,150	5,000	5,000
4,100JB	3,850JB	4,650	4,900	6325	6,500	6,750	5,050JB
4,850	3,900JB	4,300	4,100JB	6050JB	6,400	6,650JB	4,850
4,900	4,650	4,925JB	4,900	6125JB	5,800	5,400	4,925JB
4,875	4,150JB	4,650	4,450	6275	6,500	5,900	4,825JB
4,900	3,800JB	4,175	4,700	6325	5,200JB	5,100	4,950JB
4,850	4,800	4,700	4,500	6400	5,200JB	5,250	4,750JB
4,600	3,700JB	4,500JB	4,800	6425	5,025JB	5,000JB	4,550JB
4,450	4,675	4,175	4,175JB	6350	6,250JB	5,725JB	4,600JB
	3,850JB	4,525	4,450JB	6150JB	5,225JB	4,950JB	5,250JB
Average:				Average:			
4,708	4,198	4,540	4,545	6278	5,725	5,573	4,875

TABLE XIII
SUMMARY OF BREAKING STRENGTH DATA

TYPE	RESIN CONTENT percent	BREAKING STRENGTH original pounds	BREAKING STRENGTH AFTER ABRASION pounds	BREAKING STRENGTH AFTER WEATHERING pounds
I	0	406	314	415
	1.84	423	306	400
	3.16	422	314	395
	3.92	424	328	400
II	0	576	366	
	2.10	584	381	547
	3.03	585	411	534
	4.19	580	455	541
III	0	868	546	854
	2.21	825	577	746
	3.22	876	654	809
	3.84	868	683	803
IV	0	1,160	665	1,123
	1.78	1,165	665	1,095
	2.81	1,176	718	1,085
	4.04	1,173	711	1,083
V	0	1,685	853	
	2.25	1,711	1,002	1,769
	3.06	1,745	1,163	1,438
	4.25	1,675	1,196	

TABLE XIII

SUMMARY OF BREAKING STRENGTH DATA

(continued)

TYPE	RESIN CONTENT percent	BREAKING STRENGTH original pounds	BREAKING STRENGTH AFTER ABRASION pounds	BREAKING STRENGTH AFTER WEATHERING pounds
VI	0	2,438	1,110	2,390
	2.19	2,395	1,205	2,195
	3.18	2,340	1,230	2,265
	4.40	2,070	1,400	1,988
VII	0	2,745	1,150	2,620
	2.06	2,690	1,333	2,708
	3.22	2,755	1,465	2,653
	3.82	2,425	1,803	2,315
VIII	0	3,580	1,575	3,673
	2.27	3,510	1,563	3,343
	2.94	3,300	1,710	3,550
	3.98	3,130	1,985	3,388
IX	0	4,700	1,610	4,708
	1.84	4,650	1,948	4,198
	2.78	4,530	1,985	4,540
	3.98	4,465	2,408	4,545
X	0	5,300	2,220	6,278
	2.10	6,380	2,640	5,725
	3.47	5,760	3,348	5,573
	4.45	5,235	3,980	4,875

TABLE XIV

BREAKING STRENGTH AFTER ABRASION
VS.
BREAKING STRENGTH RETAINED (%)

TYPE	RESIN CONTENT	BREAKING STRENGTH AFTER ABRASION	BREAKING STRENGTH RETAINED	PICKS PER INCH	LINEAR FILAMENT DENSITY x10 -3
	percent	pounds	percent		
I	0	316	77.8		
	2	316	74.9	11.8	22.3
	3	316	74.9	11.7	22.1
	4	316	74.9	11.6	21.9
II	0	366	63.5		
	2	374	64.0	9.70	24.5
	3	411	70.3	9.78	24.6
	4	440	75.9	9.70	24.4
III	0	546	63.0		
	2	570	69.0	8.74	33.0
	3	630	72.0	8.77	33.2
	4	685	79.0	8.77	33.2
IV	0	665	57.4		
	2	685	58.8	6.85	34.5
	3	700	59.5	6.79	34.2
	4	710	60.5	6.79	34.2
V	0	853	50.6		
	2	1,000	58.5	6.72	50.9
	3	1,010	58.0	6.70	50.9
	4	1,030	59.0	6.79	51.3
VI	0	1,110	45.5		
	2	1,200	49.2	4.80	48.5
	3	1,240	50.9	4.80	48.5
	4	1,320	54.1	4.80	48.5
VII	0	1,150	41.9		
	2	1,320	48.0	4.86	57.2
	3	1,430	51.0	4.86	57.2
	4	1,800	65.5	4.90	57.6
VIII	0	1,575	44.0		
	2	1,575	44.0	5.66	51.2
	3	1,620	45.3	5.50	55.5
	4	2,000	55.9	5.50	55.5

TABLE XIV

BREAKING STRENGTH AFTER ABRASION
VS.
BREAKING STRENGTH RETAINED (%)
(continued)

TYPE	RESIN CONTENT	BREAKING STRENGTH AFTER ABRASION	BREAKING STRENGTH RETAINED	PICKS PER INCH	LINEAR FILAMENT DENSITY $\times 10^{-3}$
	percent	pounds	percent		
IX	0	1,610	34.2		
	2	1,960	41.7	5.85	58.9
	3	2,140	45.5	5.93	59.7
	4	2,320	49.4	5.82	58.6
X	0	2,220	35.2		
	2	2,600	41.3	4.80	64.6
	3	3,120	49.5	4.70	63.2
	4	3,660	58.1	4.72	63.5

NOTE:

1. ABRASION RESISTANCE (pounds) was obtained by reading the breaking strength from the abrasion graphs at the given resin contents.

2. BREAKING STRENGTH RETAINED (percent)
$$\frac{\text{BREAKING STRENGTH AFTER ABRASION (lbs) of TABLE XIV}}{\text{BREAKING STRENGTH AT 0\% OF TABLE XIII}} \times 100$$

3. LINEAR FILAMENT DENSITY was not calculated at 0% due to the elongation while undergoing abrasion materially affecting the picks per inch.

FIGURE 1 BREAKING STRENGTH VS RESIN CONTENT OF ABRASION TESTED BRAID, TYPES I THROUGH V

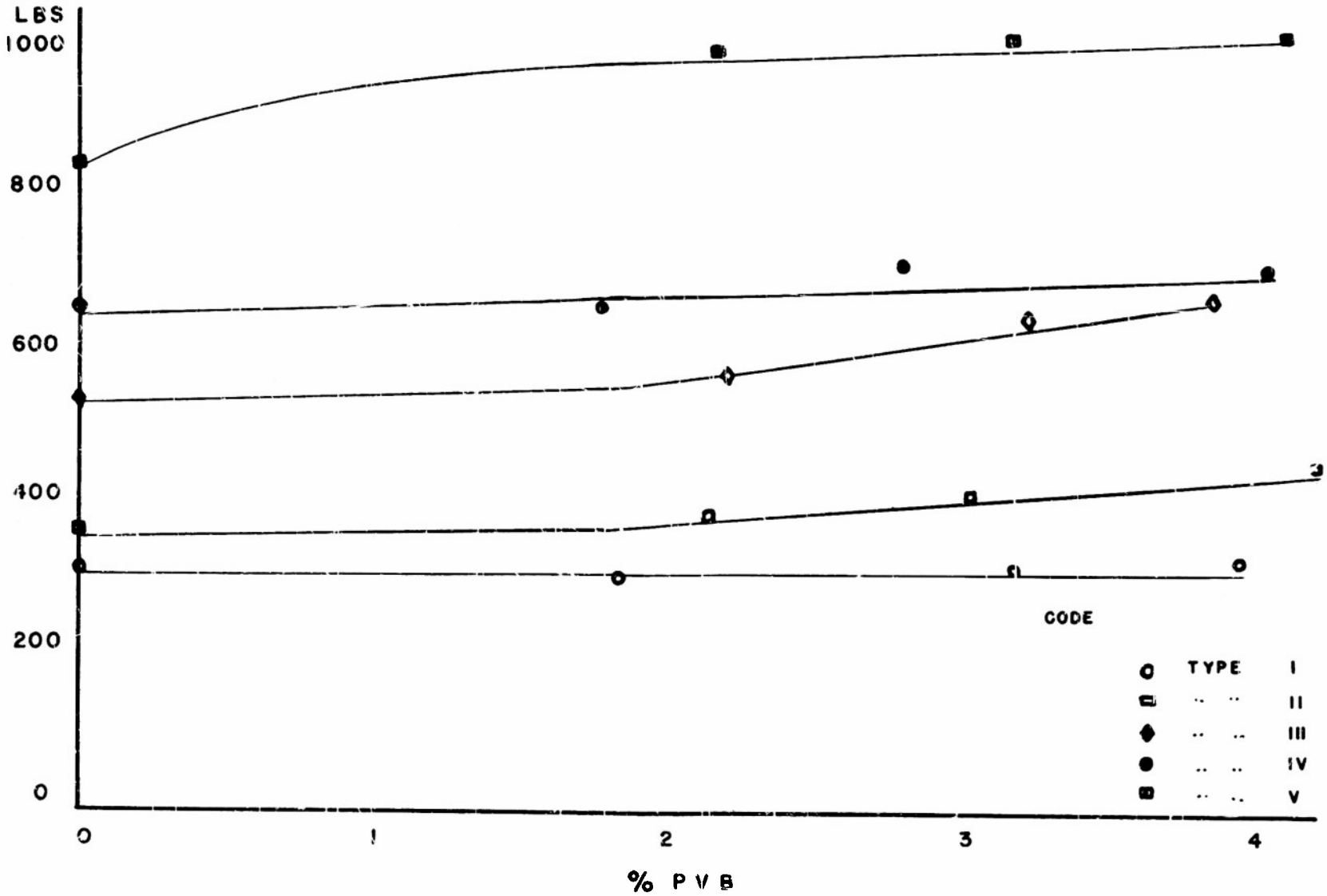

FIGURE 2 BREAKING STRENGTH VS RESIN CONTENT OF ABRASION TESTED BRAID, TYPES VI THROUGH X